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U.S. Nuclear Regulatory Commission
ATTN: Ms. Deborah A. DeMarco
Office of Nuclear Material Safety and Safeguards
Program Management, Policy Development, and Staff
Office of the Director
Mail Stop 8D-37
Washington, DC 20555

Subject: Transmittal of Paper for Publication in the Risk Analyses Journal

Dear Ms. DeMarco:

The purpose of this letter is to transmit for your programmatic review a paper which will be submitted for publication in the Risk Analysis Journal. The editors of the journal intend to publish this paper as a perspective paper, which is geared more toward publishing authors opinion rather than an organization's technical position. The paper is by S. Mohanty and B. Sagar and is titled "Importance of Transparency and Traceability in Building a Safety Case for High-level Radioactive Waste Repositories." If you have any questions regarding the technical content of the paper, please contact either me at (210) 522-5252 or Dr. Sitakanta Mohanty at (210) 522-5185.

Sincerely,

Budhi Sagar, Ph.D.
Technical Director

BS/cw

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IMPORTANCE OF TRANSPARENCY AND TRACEABILITY IN BUILDING A SAFETY CASE FOR HIGH-LEVEL NUCLEAR WASTE REPOSITORIES

by

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Short Title: Importance of Transparency and Traceability

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ABSTRACT

The complexity of the safety case for a high-level nuclear waste repository makes it imperative that deliberate and significant effort be made to incorporate in it a high level of transparency and traceability. Diverse audiences, from interested members of the public to highly trained subject matter experts, make this task difficult. A systematic study of the meaning of transparency and traceability and the implementation of the associated principles in preparing the safety case is, therefore, required. In this paper, we review the existing knowledge and propose topics for further investigation.

Key words: Performance Assessment, Transparency, Traceability, Nuclear Waste Repository, Software, Documentation, Risk Assessment

Introduction

High-level nuclear waste repositories are designed to protect human health and the environment during two distinct periods: (i) the time before a repository is closed and sealed—this period includes the operational period during which the waste is received at the site, prepared for disposal, and placed underground, plus any extended period for which the repository may be kept open for technical and societal reasons; and (ii) the period after the repository is permanently sealed. The preclosure period may last from a few tens of years to a few hundreds of years, while the postclosure period may extend from thousands to millions of years. Depending on the amount of waste to be disposed, the repository may occupy an area of several hundred hectares, and the potentially affected surface environment could be even larger.

The safety case for these facilities rests, to a significant extent, on analyses that simulate their performance over these long periods of interest relying on mathematical models and using a large amount of data. A somewhat analogous evaluation called the integrated safety analysis is performed for the preclosure period[1] and the postclosure analysis is called the performance assessment or, alternatively, a safety or risk assessment.[2] Performance assessment is a systematic analysis that identifies the features, events, and processes (FEPs) (i.e., specific conditions or attributes of the geologic setting, degradation, deterioration, or alteration processes of engineered barriers and interactions between the natural and engineered barriers) that might affect performance of the geologic repository, examines their effects on performance, and estimates the average annual dose.[3] An integrated safety analysis and a performance assessment contain system descriptions and supporting databases, scenario analyses, consequence analyses, performance measure calculations, sensitivity and uncertainty analyses, and a comparison of estimated performance to regulatory requirements. Because of the extended time and large space scales involved, the presence of interdependent geologic and engineered components, and a variety of data and model uncertainties, the postclosure performance assessment is usually quite complex. In most countries, an implementor proposing to build a high-level nuclear waste repository is required by regulation to conduct an integrated safety analysis and a performance assessment and submit them to the regulator, as part of the application for obtaining a license to construct and operate a proposed repository. For instance, the disposal of high-level nuclear waste in the United States involves the U.S. Department of Energy as implementor, the U.S. Nuclear Regulatory Commission (NRC) as regulator, with (proposed) regulations described in 10 CFR Part 63.[3] The regulator reviews the integrated safety analysis and the performance assessment (and other parts of the license application) to decide whether to grant or deny a license.

The regulator is interested in conducting an efficient and effective review. Transparency and traceability in the implementor's integrated safety analysis and performance assessment are necessary for the regulator to develop confidence in whether or not the proposed facility will satisfy the regulatory criteria. Besides the regulator, other groups, such as affected state and local governments, advisory committees, peer groups, and members of the public, also have a stake in the project and, therefore, have an interest in understanding the safety case. These other stakeholders may be interested in understanding the effects of the proposed project, understanding the considerations used to develop the proposed design, thoroughly critiquing the safety case, or gaining confidence in the implementor's analysis.

In the following sections, we provide working definitions for transparency and traceability, and describe the transparency and traceability needs for each of the major areas of performance assessment. Finally, we identify the challenges and future outlook in the area of transparency and traceability. Most of the discussion focuses on performance assessment, but it is equally applicable to the integrated safety analysis.

Definitions

Briefly, *transparency* implies "readily understood," and traceability implies "easily tracked."

The American Heritage Dictionary defines *transparency* as the quality or state of being easily detected, seen through, and readily understood. The Nuclear Energy Agency (NEA)[4] formally defines a transparent safety report as, " ... a report that is written in such a way that its readers can gain a clear picture, to their satisfaction, of what has been done, what the results are, and why the results are as they are." B. King[5] indicates that transparency exists when there are systems (e.g., procedures, protocols, and conventions) in place that ensure the reliability of information, processes, and methods and provide the reviewer or user with clear evidence of reliability. Verification of truth of technical explanation, proof of authenticity, and proof of legitimacy of approaches and actions are quoted in the literature as some of the reasons for which transparency is sought.

The American Heritage Dictionary defines *traceability* as the quality or state of being ascertained, established, or attributed as a result of retracing or reviewing. Traceability is defined by NEA[4] as "an unambiguous and complete record of the decisions and assumptions made and of the models and data used in arriving at a given set of results." Traceability exists when there is an unbroken chain linking the result of an assessment with models, assumptions, expert opinions, and data used in the formulation of the result.[6] Though a narrow definition, the term traceability is almost always quoted in the literature in the context of enabling the reviewer to reproduce the entire analysis.

As a working definition, we use transparency and traceability to refer to those attributes of a presentation that promote understanding at all levels of detail and allow the reader to reproduce the results or verify their authenticity and scientific accuracy. In the following section, these attributes are discussed with respect to the main steps of conducting a performance assessment, which include system description and scenario analysis, model abstraction, data acquisition, development of computer code, and results of the assessment. Another section of this paper is concerned with transparency and traceability in the documents that describe the performance assessment.

System Description and Scenario Analysis

The first important step in performance assessment is a system description and scenario analysis. In this step, the relevant features of the system are identified, and plausible future conditions to which a repository may be subjected are determined. FEPs at the site are evaluated to identify those significant enough to warrant inclusion in the assessment model. Features are the physical components of the repository system, processes act on features continuously in time, and events act on features at discrete times and may alter the features or the rates of processes. Whether a complete set of FEPs has been identified (and, subsequently, whether a complete set of scenarios has been defined) is always a potential source of uncertainty in performance assessment. To resolve this uncertainty, a systematic approach may be required where the enumeration of plausible FEPs includes input from all stakeholders, not just subject matter experts of the implementor. Additional support may be derived from the examination of similar studies carried out in the international arena (for instance, through comparison with the FEPs international database).[4] Transparency and traceability would be served by describing the method used, the range of participants, and an overall evaluation of completeness. Typically, a model is built to capture the relevant FEPs in the analysis. There can be virtually an infinite number of combinations of these FEPs)especially when the FEPs are too finely divided) that may need to be evaluated for their significance to performance—a monumental task for an implementor to develop and a stakeholder to review. To yield a more manageable set of FEPs, some may be eliminated, based on low probability, low consequence, or other arguments. The identification of the essential FEPs and the elimination of others have important implications for traceability and transparency. For instance, in a systematic approach, FEPs are first identified, then classified, and finally screened out, if appropriate, from further consideration. These excluded FEPs will likely undergo careful scrutiny by the stakeholders and, therefore, great transparency and traceability in explaining the exclusion process is needed. This requires a traceable record of the criteria and the rationale used for identifying, classifying and excluding the FEPs, all approximations or simplifications made, and all final screening decisions made when there is ambiguity (e.g., too fine a granularity in defining FEPs may result in screening out FEPs using low probability criterion or the decision to include or exclude a FEP is not unequivocal). Tools such as interaction matrixes and interaction diagrams[7] may be employed to provide a roadmap that will enhance understanding of the relationship between relevant included and excluded FEPs and generic, as well as unique, screening rationale. Ultimately, the FEP analysis approach should provide a record showing that all excluded FEPs truly pose a negligible risk.

FEP analysis is an aspect of the performance assessment where a nontechnical audience can postulate any number of FEPs and potential scenarios. Consequently, the implementor must be ready to show that the FEP in question has been considered in the process, either uniquely or as a part of a broader FEP. If the FEP in question has been eliminated, the implementor must have sound supporting arguments. If the FEP analysis approach is structured with an appropriate hierarchy (from a few broad classes or categories at the higher levels down to tens or hundreds of specific instances of those classes at the lowest level), a wide variety of reviewers will be able to readily determine (transparently) the final status of individual FEPs and follow the reasoning behind that status (traceability).

Model Abstraction

One or more performance assessment models are developed using the FEPs included in the scenario analysis process because of their potential importance to performance. Abstracted models (conceptually simplified models) are developed to represent the retained FEPs and frequently incorporate probabilistic methods to address inherent uncertainty and variability.

Transparency and traceability in modeling should give any stakeholder a full understanding of the mathematical framework for a conceptual model through the description of its (i) objectives; (ii) technical basis; (iii) connection between model assumptions, site features, and the proposed design; (iv) simplifications adopted to facilitate construction of the model; (v) parameters, including a description of associated uncertainty and variability; and (vi) the computational approach. Traceability should allow the reviewer to gain an understanding of when, by whom, and on what basis various decisions and assumptions were made[8] during the abstraction process. Because assumptions and simplifications are vital to model abstraction, any inconsistency in their application among the various models, should be acknowledged, explained, and justified.

Transparency and traceability can be achieved by ensuring that a process is in place that can identify and distinguish among facts, expert judgment, uncertainties (e.g., in models and data), value judgments, levels of significance, and open questions.[9] Value judgment (i.e., judgment outside the norms of established science) has an influence on the issues ultimately addressed in the performance assessment. Smith[10] points out that it is important in the performance assessment not to mix or confuse value judgments with objective facts.[11,12] Bias or a distortion of assessment will result from mixing facts with value judgments and information that confirms only one's own views (distortion).[9] Documentation should clearly indicate how such biases have been avoided.

The range of applicability of the model(s) used to evaluate performance should be defined. Discussion is required on major design alternatives that were considered, the reasons the selected approaches were chosen, and the reason other alternatives were not selected. Uncertainty in conceptual models occurs when several conceptual models describe current understanding but have different implications on estimated future results. For instance, there may be distinctly different models describing infiltration of groundwater through the unsaturated zone to the repository horizon. These cases require careful documentation that explains the underlying reasons a single model cannot be selected and examines the effects of the different models on potential impacts. If a decision is later made to employ one model, the reasons for its selection should be clearly stated.

When there is no consensus on the applicability of data or models either because of a difference of opinion or a high degree of uncertainty, an approach often adopted to resolve the situation is an evaluation by an expert panel. To ensure authenticity of the use of an expert panel and the state-of-the-art knowledge, independent reviewers should be able to verify that the expert review process is formal, clearly defined, clearly documented, and follows a well-established guideline.

Finally, information provided should be sufficient to allow a stakeholder to trace the model development process from fundamental background information (such as FEPs, site characterization, and design information) to the computer code (forward traceability) and back (backward traceability).[13] A map (e.g., a "road map" diagram, a traceability matrix, or a cross-reference matrix) to explain the conceptual features (e.g., patterns of volcanic events) and processes represented in the performance assessment models and their associated algorithms is expected to be present. The discussion should focus on the factors of greatest importance about which there is greatest uncertainty.

Data

The validity of performance assessment results depends on the validity of the model(s) as well as the validity of data used by the models. Therefore, transparency and traceability should allow (i) an understanding of the source, quality, and validity of data and their use in the performance assessment; (ii) verification of sufficiency of data collected from the site-specific field-study, laboratory, and/or natural analogs to adequately define relevant parameters and conceptual models; and (iii) an understanding of how data values for model parameters were derived from raw data.

A strong quality assurance program can ensure data traceability through an established audit trail. The audit trail should clearly show how model parameter values were derived from raw data, whether measured in the laboratory or field or obtained through expert elicitation. The same audit trail should also allow an assessment of data used to guide modeling assumptions and decisions, even if such data might have been controlled by the quality assurance program. Sufficient information should be provided regarding quality assurance controls placed on the data used in the performance assessment including data collection procedures, use of standards, data reduction, and data analysis.[14] Proper data classification can greatly simplify and reduce data traceability requirements. For example, a physical constant does not need more than a simple reference to a handbook or a well-recognized database.

Repository attributes identified through performance assessment as being important or uncertain may be evaluated further through a performance confirmation program. Performance confirmation involves a program of tests, experiments, and analyses that are conducted to evaluate the adequacy of the information used to demonstrate compliance with the performance objectives.[3] Understanding can be enhanced through a clear presentation of information related to appropriate identification and selection of candidate parameters and models to be confirmed. Traceability between performance confirmation data and the performance assessment model parameters should be adequately established. Rationale for selection of performance confirmation tests and data collection methods should be explained in sufficient detail. Effects of any potential change in condition, parameter, model concept, or design should be discussed.

Results of Assessment

The results of a performance assessment are quite broad. Of special importance is the estimate of the performance measure (e.g., in the United States, the maximum of the mean annual dose per year within the compliance period of 10,000 years), which is generally compared to quantitative regulatory limits. Intermediate results give information relevant to other regulatory requirements, such as the effectiveness and contribution of the barriers comprising the disposal system. Results from sensitivity analyses (including uncertainty and importance analyses) are used to ascertain the influential parameters and significant repository components and processes. Such information directly contributes to reducing data uncertainty by identifying optimal choices for additional data collection and/or analysis for better constraints and better understanding of processes.

Performance assessment results should be traceable to the critical assumptions, input parameter values, models, and treatment of uncertainty. Adequate presentation and appropriate use of intermediate results provide transparent and traceable linkage between release, mobilization, and transport components of the model with the key performance assessment results. Subjective standards, such as a requirement for "significant" contribution from barriers, may dictate a greater transparency in the rationale employed.

Performance assessment results are only as good as the models and parameters used in the assessment; for example, an error in the performance assessment may result from an incorrect analytical solution for a model. Transparency and traceability mechanisms should make the process of finding such errors less cumbersome. Supporting hand calculations, showing the connections between the input data and final key results, will improve the transparency of the results and help reveal potential errors.

Computer Code

Any computer code to evaluate public safety should produce results that can be accepted with confidence. Therefore, it is important that a performance assessment code be transparent and traceable. Code design (control logic and data structure, external interfaces, the user interface, and error handling), conceptual treatment of the model and data, information flow within the code, code outputs in relation to calculational steps, and code validation should be clearly explained.

Modularization (i.e., logical partitioning of the system into small components), a fundamental principle of structured code design, greatly enhances transparency.[15] The performance assessment code should, therefore, be modularized in such a way that the modules are as independent as possible. Measures of modularity are *coupling* and *cohesion.* Low coupling is achieved when two modules communicate only through parameters with each parameter representing only the necessary communication of data between modules. Low coupling between modules indicates a well-partitioned system (i.e., a low degree of interdependence). Cohesion is the measure of the strength of functional association of instructions or groups of instructions within a module.

Highly cohesive modules contain only elements that contribute to the execution of one, and only one, problem-related task. A high degree of cohesion leads to less coupling and enhanced transparency.

Code commentary (sometimes referred to as internal documentation) is vital to the transparency of the computational steps. Transparency is achieved if functions, interfaces, and data used are fully described. Consistent variable naming conventions, a logical structure, and the use of an appropriate format in the code enhance transparency. Although code standards, such as indentation or white space, are often viewed as too prescriptive, their use in the performance assessment computer code will enhance the understandability of implementation. Moreover, sufficient information describing the evolution of the code (e.g., a record of changes and explanations, with dates and names of programmers) provides traceability to the evolution of the code through time.

Code validation is a key component of confidence building for any computer code. Code validation involves testing and evaluating a completed code to ensure the software is computing correctly. The goal should be to demonstrate code validity to the level of confidence that the code can perform all intended functions. A systematic approach to the identification of test problems and associated test findings will provide transparency and will ultimately contribute to the confidence-building process.

Documentation

Performance assessment documents are the primary vehicles used to communicate the safety case to stakeholders. These documents should tell the entire story from site characterization to the final results of the safety case, including how problems, limitations, and uncertainties are identified and isolated in the performance assessment, and how stakeholder concerns were resolved. The document should provide the breadth and depth of coverage so that the complete information is available to satisfy a reviewer's interests, which may range from an overview of the work completed and its outcome to a narrow focus on special issues. Quality of presentation, style, tone of presentation, organization of information, and document structure are some of the key attributes of transparency and traceability in documentation.

The quality of documentation is based on two attributes, completeness and clarity. Documentation should be complete with needed information present and necessary details included. For example, the regulator's guidance documents (e.g., NUREG documents issued by the NRC) tell the regulator's staff how to review a license application. These documents provide important insights to the implementor on how to structure the performance assessment document so it contains all information regulators will likely seek during a review process. Document content should be presented at an appropriate level of detail; the relationships between sections within a document should be straightforward; the terminology should be appropriate, precise, consistent, and understandable; and the message of each section and the entire document should be precise and unambiguous. Clarity is lost when ambiguity exists. Using the same term, phrase, or mathematical symbol to mean different things or using different terms for the same thing leads to ambiguity. Terms and phrases should be used in a fashion that is consistent with similar studies and publications in the literature, including international work, and any exceptions should be clearly noted.

The document should have a tone that will highlight safety and vulnerability. For example, redundancy of system components and safety factors in parameters should be highlighted. Also, the vulnerabilities, such as the presence of backfill leading to early corrosion because of moisture retention around a waste package should be documented. The document should reflect thoroughness of analysis. A chain of credible and verifiable references should be provided for the defensibility of the scientific basis. Insufficient, incomplete, or confusing information in the descriptions of models, parameters, and approaches will obscure transparency. Care should be taken to ensure there are no circular arguments in the text of the document. Strong statements that are unsupported weaken a reviewer's confidence.

Performance assessment documentation should have a balance in the level of detail, clearly state assumptions and simplifications made, and properly reference the source (e.g., dose-conversion rates). This may require a hierarchy of documents. In a hierarchical system, a suite of lower-level technical reports and documents supports the performance assessment documents. Traceability of information must be established in the hierarchy of documents from the source to its eventual use in performance assessment. To obtain a complete understanding, the reviewer may need to examine information in supporting technical documents and reports, which should be readily available. The structure of the performance assessment document should facilitate in-depth reviews so the technical reviewer does not have to search an entire document or a set of documents to compile information for specific topics of interest.[4] A reviewer should not have to search multiple documents for answers to key performance assessment questions, but if multiple document searches are required, adequate mapping (e.g., cross-reference matrices) to external information should be provided. But if the reviewer's inquiry necessitates information at a greater depth, "road map" diagrams, traceability matrices, and other graphics should explain the relationships within and between documents. Another method to simplify searches is the use of a keyword index for all lengthy documents and perhaps a global keyword index for a collection of performance assessment and supporting documents.

Before the release of the performance assessment document, reviews should be conducted to ensure transparency and traceability. A vertical review should be conducted to ensure results from analyses, calculations, and models are traceable to their origin, which could be at the lowest level of documents in a hierarchical tree. A horizontal review will ensure consistency of inputs, texts, and conclusions across the individual documents. Text display of results should be consistent with figures and tables referred to in the text.

Documentation of performance assessment computer codes, especially internal or external documentation describing the code, is important. Supporting documentation (e.g., user's manuals, design documents) are needed to clearly describe code structure and relationships between modules. The documents should describe the overall structure of the performance assessment code and the coupling of models using structure charts and data flow diagrams. The description should be sufficient to enable a reviewer to run the computer code and understand the modules, the flow of information, and the presentation of the abstracted model (i.e., look-up table, response surface, etc.).

Challenges and Outlook

While the need for transparency and traceability is well recognized, there is no standard methodology to develop a transparent and traceable assessment. Therefore, the process remains highly subjective. Research initiatives should be encouraged to standardize the analysis and documentation process. While the depth of information required might vary from one program to another, many types of information required are common to all waste disposal programs. Without a standard, *ad hoc* actions, in response to comments from interested parties, may lead to an uneven product.

Some international high-level waste programs have gained technical acceptance, but they have failed to achieve public acceptance because of the absence of effective methods to convey technical findings to the public. The technical findings, as well as other important ethical and societal issues should be part of the public's decision-making process. Performance assessment is an area that can be made accessible to all stakeholders if an appropriate level of transparency and traceability can be provided. Some stakeholders have a need to assess the proposed disposal facility in the context of other risks and decisions made by society, and to be allowed to form independent, objective opinions on the issues.

Performance assessment documents are usually written for reviewers who are expected to be well informed on the substantive technical issues and the methodologies used in the performance assessment. To make performance assessment accessible to a broader audience, more attention must be given to the types of documents that are best for a general audience, the extent of transparency and traceability that is appropriate and the depth of the scientific information that should be presented so the stakeholders can more clearly comprehend the bases of the performance assessment results.

Exhaustive traceability is vital from a regulatory perspective and to demonstrate scientific authenticity. In the current approach, traceability lessens transparency by making the documents less readable. It appears that extra effort will be necessary to appropriately convey the process and findings of a performance assessment to all stakeholders whose bases for judgments are not readily addressed by more traditional technical explanations. Factors influencing public perception of scientific studies and specific issues, such as the way the stakeholders receive and process performance assessment information, should be investigated. Armed with such knowledge, the implementor can develop performance assessment presentations for the widest possible audience while ensuring the intended messages remain transparent and traceability is maintained.

There is an initiative in the U.S. Government to communicate with the public in "plain English." This initiative is consistent with the goal of taking scientific findings to the general public, and it will require performance assessment documents to be written in a clear, concise manner at the level of comprehension of all stakeholders with minimal specialized technical jargon. Technical experts should develop special writing skills or should use assistance from specialists to prepare technical documents in "plain English" for the general public.

There appears to be some disagreement in the regulatory community about tailoring performance assessment documents to respond to the differing needs of the general public and technical experts. Instead of requiring one document for all stakeholders, some agencies may require multiple documents because the regulator may need more detail than other stakeholders. Multiple documents may be effective (but require greater documentation effort), largely because transparency is audience dependent. That is, a document that is transparent to a regulator or practitioner of performance assessments may not be transparent to a member of the public.[4] It may not be possible for all stakeholders (e.g., public, environmental groups, state government, or regulators) to understand all technical issues in detail, nor is it possible for technical experts to fully understand each other's disciplines.[11] The challenge is to produce a set of documents structured to facilitate disparate in-depth reviews to serve stakeholders with differing perspectives.

Recent advances in electronic publications and electronic search capabilities provide a great opportunity to improve traceability. For example, it is feasible to make all documents in the hierarchy available to the reviewer. The reviewer can then readily trace information from one document to the other or search through multiple documents for information on specific topics. The successful application of this technology requires some effort by the implementor to facilitate the review process (e.g., through key word searches). Recent advances in the programming paradigm also provide an opportunity for better transparency and traceability of the performance assessment computer code. Object-oriented programming languages offer graphical (i.e., visual) display of linkage among modules and data use. The programming languages also provide a level of self-documentation that may improve transparency within the code.

Because performance assessment encompasses such a broad range of issues, the NRC has recently adopted an initiative to reduce the regulatory burden on the licensee by preparing for a risk-informed, performance-based review approach. Risk-informed, performance-based regulations call for the use of risk insights, engineering analysis and judgment, and performance history to (i) focus attention on the most important activities, (ii) establish objective criteria based on risk insights for evaluating performance, (iii) develop measurable or calculable parameters for monitoring system and licensee performance, and (iv) focus on the results as the primary basis for regulatory decision making (proposed NRC regulation 10 CFR Part 63). The risk-informed, performance-based approach will ensure the review focuses on those items most important to performance. This approach implies the licensee will not need to document all aspects of an evaluation to the same depth and breadth, but this approach does not mean that less important aspects are not documented; rather the amount of evidence (hence, traceability) will be commensurate with the relative risk from a component, process, or aspect of the repository. The licensee must document all aspects of the repository, but the risk-significant information requirement will taper down as one goes to the depth (less significant aspects) of a systematic evaluation. The risk-informed, performance-based approach should prevent the reviewer from being overwhelmed with information and, more importantly, avoid diverting attention and resources to matters that are not important to ensuring safety.

Conclusions

Transparency and traceability are key attributes of an acceptable and successful performance assessment. Although a transparent and traceable performance assessment cannot guarantee truth of technical explanation, authenticity, and legitimacy of approaches, it provides an independent reviewer information from which to make judgments and conclusions regarding the ability of a facility to meet the performance objectives. The ease with which an independent reviewer is able to comprehend and duplicate the analysis is a measure of success in presenting a safety case to the regulator and other stakeholders. Additionally, a well-documented and well-constructed performance assessment provides self-proving documentation for legal challenges. A strong quality assurance program can help assure transparency and traceability of performance assessment documentation by providing the appropriate checks to ensure the desired goal of comprehension by independent reviewers is met. Even though all information may not be contained in a single document, the system of procedures, protocols, and conventions followed by the implementor must ensure the reliability of data, processes, and methods, providing independent reviewers with the ability to judge the adequacy of a performance assessment.

The topic of transparency and traceability is highly subjective. There is no standard formula available to make a license application transparent and traceable. Therefore, the goals of transparency and traceability can be achieved by interacting with the potential stakeholders at the developmental phase of the license application. However, a standardized procedure should be developed for conducting and documenting performance assessments in a way that will be transparent and traceable. Recent developments in the use of electronic documents and object-oriented programming languages should be used to full advantage to improve transparency and traceability. The risk-informed, performance-based approach will provide an avenue to achieve transparency and traceability with less effort by focusing on what is important to repository performance.

Finally, although this paper focuses on nuclear waste, the need for transparency and traceability in risk assessment applies to a wide variety of projects, notably those that are complex and controversial. Consequently, there may be valuable lessons available. Therefore, any future studies regarding transparency and traceability of performance assessment will be valuable in a broader context.

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